PATENT SPECIFICATION 1,073,739

DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION

Electrohydraulic System and Working Fluids therefor.

We, GENERAL ELECTRIC COMPANY, of 1 River Road, Schenectady 5, New York, United States of America; a corporation organised and existing under the laws of the State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to an electrohydraulic spark discharge system having an improved working medium for greater operating efficiency. More particularly, the present invention relates to an improved electrohydraulic system with a modified dielectric liquid operatively associated with the spark gap to reduce energy loss during the discharge cycle.

Electrohydraulic systems convert electrical energy to a steep pressure wave in a liquid medium for useful work. The energy released takes place by spark discharge across a suitable gap at sufficiently high rates to cause ionization of liquid in the gap. The working force represented by the pressure wave is of sufficient magnitude to form metal members in communication with the working fluid for such useful operations as forging, hole drilling, bending, and the like. Utilization of the electrohydraulic working force has been suggested for such other diversified applications as rock crushing, pile driving, material compaction, and vibratory devices. Past systems often employ conventional dielectric liquids such as water or hydrocarbon oil for the energy conversion medium. Alternatively, ionic liquids such as aqueous salt solution were found useful since the discharge phenomenon depends primarily upon ionization of the working fluid rather than ionic conductance therethrough. Faster ionization favorably influences rate of energy release and traditionally the working fluid has been a single phase liquid with uniform vaporisation characteristics. It has been reported that discharge occurs more rapidly with consequent faster rate of pressure buildup in salt water. On the other hand, it has also been reported that a soluble ionic compound in the working fluid lowers conversion efficiency of electrical energy to the pressure wave. An electrohydraulic working fluid providing faster discharge for greater pressure generation in the medium without attendant lower energy conversion would be of great benefit.

According to the present invention an electrohydraulic spark discharge system comprises apparatus producing a high-energy pressure wave in a fluid for the working of metals and other mechanical working applications wherein the fluid is a dielectric liquid containing substantially insoluble electrically conducting particulate solids.

Reference should now be made to the accompanying drawings in which:—

Figure 1 is a schematic electrical diagram illustrating one electrohydraulic system of the invention and

Figure 2 represents a different electrohydraulic system of the invention.

Briefly, the improved electrohydraulic spark discharge systems of the invention comprise a source of high voltage electrical energy, capacitor storage means for the electrical energy, means for discharging the stored electrical energy in pulse form, and means for conducting the energy pulse to a spark gap operatively associated with a working fluid containing particulate conducting solids. The improved working fluid comprises a multiphase composition having a continuous phase of dielectric liquid and a dispersed phase of conductive particulates

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which are substantially insoluble in the liquid. The term "dispersed" as used to describe the working fluid signifies ability to be dispersed in the continuous phase by spark discharge as well as the more conventional connotation of a suspension which does not readily settle out of the liquid.

While the exact mechanism of electro-hydraulic energy conversion is a complex phenomenon not fully understood at present, some explanation of the operative principles involved serves to distinguish the present systems from conventional practice. Delivery of high voltage electrical energy to the spark gap is at a faster rate than the medium's ability to absorb the heat. Consequently, the liquid medium is vaporized in the gap vicinity undergoing at least partial ionization. Subsequent expansion of plasma bubble during the short time interval of energy release produces a shock wave in the remaining noncompressible liquid environment. Understandably, there is both a time interval for ionization to proceed across the gap and necessary energy expenditure to produce ionization. The presence of particulates in the working fluid shortens the liquid path across the spark gap. Since there is now less liquid in the gap, conceivably, the energy expenditure for gap ionization might also be reduced. Surprisingly, it has been found that a dispersion of electrically conductive particulates in the spark gap achieves both desired results. While the mechanism producing the desirable effect cannot be defined precisely as yet, the phenomenon may be analogous in certain aspects to dielectric breakdown in solid insulation. Dielectric failure of the solid occurs when an applied potential establishes an arc path throughout the entire medium. Breakdown is enhanced by presence of discontinuities in the insulation which ionize to form a conductive path under the electrical stress or exhibit electrical conductivity in the original condition. If the discontinuities originally conduct current, there will be little or no energy expenditure in ionizing this portion of the medium. Upon ionization or conduction through said discontinuities, the thickness of the insulation barrier to current flow is effectively reduced and the originally applied potential achieves conduction through the entire medium. The time interval for dielectric breakdown in solid insulation is often shortened by the nature of discontinuities in the medium. While electro-hydraulic energy conversion differs in most other aspects from the dielectric breakdown phenomenon above described, the similarities pointed out are believed helpful to better understand the functions performed by conductive particulates in the working fluid.

For practice of the invention, conductive particles may be dispersed in the working fluid by conventional technique to form a stable suspension. Emulsifiers, dispersing agents, or selection of a dielectric liquid with similar density to the particulate material provide known means for suspending solids in a liquid environment. It is also contemplated to physically circulate the working fluid during spark discharge as will be subsequently described in greater detail hereinafter in the specification. Additionally, upon spark discharge, particulates which may be settled in the liquid receive sufficient impetus to produce the desired dispersion. Preferred particulates for incorporation in the dielectric liquid are metal compositions including metal elements, alloys, and metallic compounds exhibiting good electrical conductivity, substantial insolubility in the liquid, and reasonably resistant to mechanical disintegration from the shock wave generated by spark discharge. While energy conservation is achieved at even minute concentrations of particulates in the working fluid, it has been found desirable to restrict the upper concentration limit below that resulting in decreased volume resistivity of the mixture below around 1000 ohm-centimeters. Lower volume resistivity produces other power losses during spark discharge so that the dielectric liquid of the working fluid must exhibit the mentioned resistivity characteristics. One form of undesirable energy dissipation with low resistance working fluids is spark reignition during a single pulse from the associated high energy electrical circuit. More particularly, in electrohydraulic systems, the first cycle of current across the gap is of such higher magnitude than all successive cycles that little or no useful work is accomplished during the latter discharge. Spark reignition thereby dissipates energy otherwise available during the work-producing discharge.

Having described the invention generally, it may be practiced in its preferred embodiments as hereinafter explained with reference to the accompanying drawings. Accordingly, in Figure 1 there is depicted schematically an electrohydraulic system employing the above described working fluid in association with a low impedance electrical circuit for efficient energy conversion. Electrohydraulic system 1 comprises generally a capacitor discharge circuit 2 connected to chamber means 3 housing the work gap element 4 and the working fluid 5. Capacitor discharge circuit 2 comprises a source of high voltage electrical energy 6, capacitor storage means 7 for the electrical energy, electrical discharge means 8 for releasing the stored electrical energy in pulse form, and conductor means 9 for transmitting the energy pulse received to the spark gap. A detailed des-

cription of the particular discharge circuit chosen for illustration appears in copending Application No. 43845/64 (Serial No. 1,047,730). Generally, capacitor element 10 is charged to the desired voltage level from an adjustable high voltage power supply 11 whereupon switch element 12 may be opened to disconnect the power supply from the capacitor as a safety precaution preventing stored energy from being returned to the power supply. Upon discharge of the capacitor element, the stored energy may be discharged through a three-electrode tube rectifier which provides the switch function in discharge means 8. The energy pulse received from the discharge means may thereafter be transmitted through a shielded coaxial power cable serving as low impedance conductor means 9 for carrying the energy to the spark gap. The complete discharge path of the circuit for spark discharge comprises the series connected capacitor, three-electrode tub, power cable, and spark gap with electrical return from the spark gap taking place through ground connection 13 in the circuit. Capacitor element 10 of the circuit is shown connected to current limiting resistor 14 for relief of the residual capacitor charge after discharge through the rectifier element 8 upon closure of switch 15. The time of residual charge dissipation may be shortened by closing second switch 16 in a particular time sequence after closure of switch 15. In repetitive discharge, the mentioned switch elements are normally operated only upon termination of the final discharge cycle. Spark gap element 4 of the circuit is located in the working fluid. As shown, the working fluid comprises a continuous phase of dielectric liquid 17 having uniformly dispersed therein a quantity of discrete individual metal particles 18.

In Figure 2, there is depicted schematically an electrode member 20 having associated chamber means 21 in which spark discharge is generated. For simplicity of understanding, a capacitor discharge circuit of the same general configuration described for Figure 1 may again be employed to provide successive high energy electrical pulses to the electrode. The electrode element of the embodiment performs the spark gap function of the preceding embodiment being connected in the electrical circuit as previously described. Different conductor means 22 are employed for connection of the electrode member, however, illustrating equivalent construction of a low impedance circuit to provide efficient energy conversion. Accordingly, conductor elements 22 leading from the electrode and all conductors in the electrical circuit may comprise a parallel bus bar network interconnecting the circuit components. The individual parallel oriented bus elements in the network are separated by a distance commensurate with minimum inductance at the particular circuit voltage employed for discharge. Electrode 20 comprises a longitudinally extending body 23 having a working tip portion 24 at one end of the member and electrical termination portion 25 at its opposite end. Body portion 23 consists of a solid electrically conducting rod element 26 at the center axis of the member and exending its entire length, hollow conducting sheath 27 of larger internal diameter than the rod and disposed coaxially to define a continuous annular space with the rod, and dielectric spacer means 28 occupying the annular space and bonding the sheath to the rod to form a unitary solid construction for the length of the electrode. Working tip portion 24 is formed by adjacent ends of the conducting elements interconnected with bonded dielectric and may conveniently have the conical configuration shown in order to regulate the shape and/or direction of the shock wave formed thereat. Terminal portion 25 of the electrode consists of electrical connector means 29 affixed directly to the outer surface of the sheath having an associated dielectric bushing 30 to provide electrical separation between said connector means and adjacent end portion 31 of the center conducting rod. To insure electrical separation at the relatively high operating voltages employed, it will be advisable to maintain longer path lengths across the bushing than the annular distance separating the conducting elements. A more detailed description of the embodied electrode appears in copending Application No. 42703/64 (Serial No. 1,068,440).

Chamber 21, in which the electrohydraulic work force is generated, has means associated therewith for circulating the working fluid during spark discharge. The circulation means 32 may consist of a liquid pump 33 with inlet and discharge sides connected directly to the chamber by conduit means 34 for sustained flow of the working fluid past the electrode. Liquid flow rate may thereby be established in the chamber sufficient to keep the particulate matter of the working fluid in dynamic suspension.

From the foregoing description, it is apparent that improved electrohydraulic systems have been provided. Additionally, an improved working fluid has been provided to permit more efficient energy conversion by the general process. By reason of the longer spark gap distances at given energy levels made possible with the present type working fluid, there is less erosion of pole members defining the gap opening. It is not intended to limit the invention to the preferred embodiments above shown, however. For example, use of particulates in the dielectric liquid having similar chemical

composition to the conducting elements defining the gap, surprisingly, further reduces gap erosion. Likewise, while the particulates can be finely-divided powders under approximately 100 mesh U.S. screen size for ease of suspension in the dielectric liquid, it is contemplated to employ larger size particulates for longer useful life in repetitive discharge operation. Particulates undergo gradual erosion from the shock treatment and larger size particles outlast smaller material under such conditions. It is intended to limit the present invention, therefore, only to the scope of the following claims.

WHAT WE CLAIM IS:—

1. An electrohydraulic spark discharge system comprising apparatus producing a high-energy pressure wave in a fluid for the working of metals and other mechanical working applications wherein the fluid is a dielectric liquid containing substantially insoluble electrically conducting particulate solids.

2. An electrohydraulic spark discharge system in accordance with claim 1 wherein said particulate solids are metallic.

3. An electrohydraulic spark discharge system in accordance with claim 1 wherein said working fluid is a stable suspension of metal particulates dispersed in a continuous phase of noncompressible dielectric fluid.

4. An electrohydraulic spark discharge system in accordance with any one of the aforementioned claims further including circulating apparatus for sustaining the flow of the working fluid past the electrode.

5. An electrohydraulic spark discharge system in accordance with any one of the preceding claims, substantially as described and illustrated in the accompanying drawings.

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1073739 COMPLETE SPECIFICATION

1 SHEET This drawing is a reproduction of the Original on a reduced scale

Fig. 1.

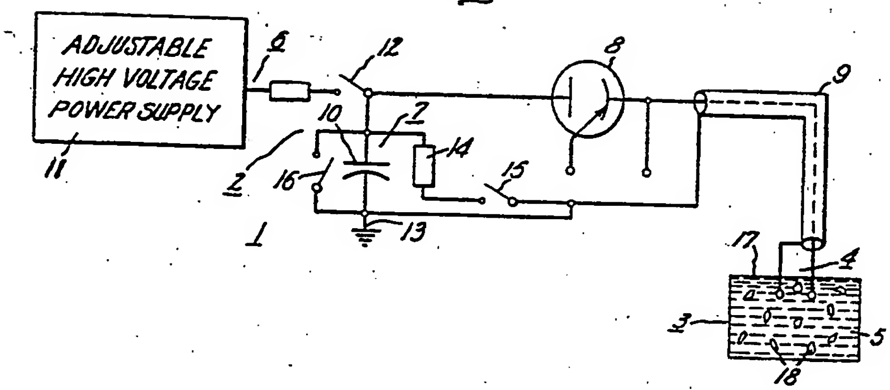

Fig. 2.